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COLLECTING COST AND PERFORMANCE DATA ON ARMY NEW AIR POLLUTION --ETC(U)
AUG 77 S R STRUSS, W J MIKUCKI

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From Boilers and Incinerators

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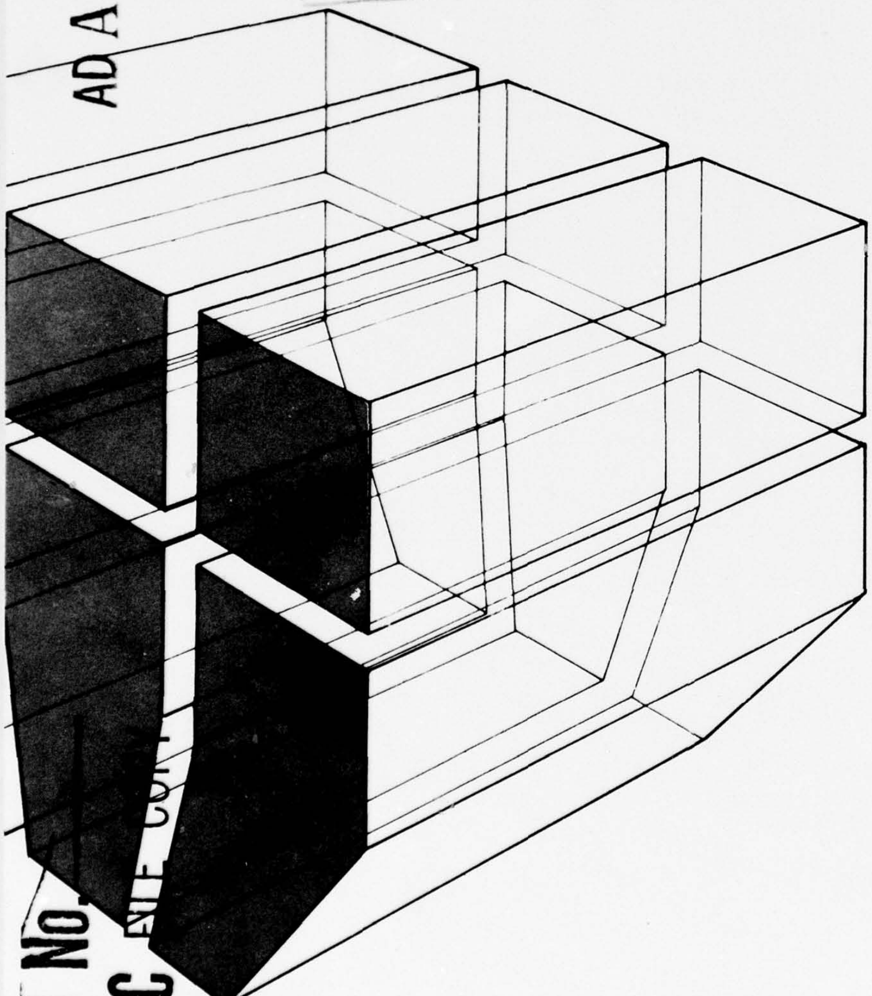

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This report outlines procedures for collecting data to conduct an air pollution control equipment cost analysis. It considers data in two basic categories: (1) data which can be collected automatically, such as power and water consumption, and (2) data which must be collected manually, such as labor and spare parts demands.

The automatically collectable data are broken down into three types:

Block 20 continued.

(1) direct cost data (consumptions), (2) operations data (collection efficiency, gas flow rate), and (3) performance data (availability, reliability). The systems presently available for extracting and handling these data are described and compared. These systems range from simple strip chart recorders to complex telemetry units. Criteria for choosing the appropriate system for a given cost study are given.

Two systems for collecting data manually are discussed: (1) a log system and (2) a cost code system which would be compatible with the Z accounting system for operations and maintenance of Army facilities.

Specific parameters to be monitored for particular types of air pollution control systems are recommended. The usefulness of the data and the way in which they should be used are also discussed.

FOREWORD

This study was conducted by the Environmental Engineering Team (ENE), Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL) for the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under project 4A162121A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task T2, "Pollution Control Technology"; Work Unit 005, "Control of Gaseous and Particulate Emissions from Boilers and Incinerators." The applicable QCR number is 1.03.006(4). The OCE Technical Monitor was Mr. Wade Sato.

Appreciation is expressed to Mr. Stephen Smith, Chief of Utilities at the Fort Benjamin Harrison Directorate of Facilities Engineering for his contribution.

COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director. Dr. R. K. Jain is Chief of EN and Mr. W. J. Mikucki is Chief of ENE.

CONTENTS

COLLECTING COST AND PERFORMANCE DATA
ON ARMY NEW AIR POLLUTION CONTROL EQUIPMENT

1 INTRODUCTION

Background

Because air pollution control technology is relatively new, there is little information available about the costs of operating and maintaining various control systems; the only long-term data available are for particulate control. Also, much of this information has been collected by control system manufacturers and therefore tends to be biased. Extrapolation of the information to cover other applications is difficult, since costs can vary with different operating conditions and maintenance schedules. The only reliable means of determining a pollution control system's operational cost is to actually monitor the system within a given application. This is especially true for military operations where labor and materials are handled differently from those of private industry.

A recent study[1] outlined air pollution control systems which may be useful to the Army within the next 10 years. When these new systems are used, it will be desirable to determine their actual value by monitoring their cost and performance.

When an air pollution control unit is installed in an Army facility, many of its operational costs become hidden within overall facility costs. Utilities, labor, and even replacement parts can be taken from resources allocated to the facility without any record being made that the costs were incurred by the control device. For example, an electrostatic precipitator (ESP) installed in a boiler plant may consume electrical power from a main supply line but not be metered separately. In this way, the power costs for operating the unit are combined with other power costs and cannot be identified as being incurred specifically by the ESP. Therefore, it is difficult to calculate electricity costs accurately, and these costs make up a substantial portion of the ESP's total operating costs.

When a certain emissions control system is purchased, the figures used to estimate its operational costs are usually determined by the manufacturer and may not be accurate for the user's intended application. These inaccuracies could be insignificant for a single system; however, if many similar units are placed at various installations, the

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[1] *Emerging Technology for the Control of Emissions From Existing Army Boilers and Incinerators*, Technical Report N-19/ADA037494 (U.S. Army Construction Engineering Research Laboratory, 1977).

error would be multiplied and could become substantial. Unless cost data are taken in a situation similar to the intended one, the values used for operations and maintenance costs will be estimates at best.

Accurate data would also provide information about the optimum operation of the control equipment. Maintenance scheduling should be based on real parameters, such as power consumption and collection efficiency, rather than on arbitrary time intervals. Downtime for inspection could also be reduced, since a unit's general operating condition could be determined while it was running. For example, a sudden increase in the flow rate through a baghouse due to failure of one or more bags would indicate when new bags were needed, and would avoid the necessity of shutting down the unit for periodic inspections. This benefit alone would outweigh the expense of a cost and performance monitoring program.

Objective

The purpose of this report is to outline the steps involved in collecting data to aid in designing a cost and performance study of an Army air pollution control unit; this information will enable installation personnel to make a sound decision about which equipment to purchase.

Approach

Although cost analysis is a well-established field, most studies still use existing data rather than collect new data. Since the concept of monitoring equipment to determine detailed cost and performance information is relatively new, few publications deal specifically with this type of analysis.

For this study, both existing information about automatic data collection systems and the input of persons involved in facilities management were compiled and presented as a single source.

Mode of Technology Transfer

The information contained in this report can be used in future updates of TM 5-815-1, *Air Pollution Control Design Manual*, or may be published by the Office of the Chief of Engineers (OCE) as an Engineer Technical Letter.

2 MONITORING TECHNOLOGY

General

To accurately determine the actual operating cost of an air pollution control device, each parameter incurring a cost must be monitored, e.g., power, water, and chemical consumption, labor, and replacement parts. Some of these can be monitored automatically, while others may require manual methods such as data logs or worksheets.

Any parameter which can be measured directly can be monitored automatically. Electronic sensors can measure pressure, temperature, flow rate, and other quantities, and meters with visual readouts can be interfaced with a data-handling system to provide a continuous or semicontinuous record of consumption. In the same manner, dry chemical consumption can also be measured by recording the feed rate from a conveyor drive motor.

Operation and Maintenance Data

The operating cost of any piece of equipment is meaningful only the service supplied by it is known. An idle machine costs little operate, but also produces little. Thus, the operating cost of an air pollution control unit is a function of its output. A unit is not economical unless it achieves the necessary collection efficiency. A unit designed to handle a certain job can be operated more economically by reducing its inputs; however, the operating costs would then be invalid, since the unit's purpose would not have been fulfilled. It is therefore necessary to monitor the collection efficiency of a pollution control unit not to determine a direct cost, but to evaluate its performance.

Stack gas flow rate is another parameter not directly related to cost, but necessary from a performance standpoint. This value, along with the collection efficiency, indicates the service being supplied by a pollution control unit.

Performance data would also be valuable for optimum operation and maintenance of the pollution control equipment. As a unit is used, its performance will deteriorate, and it will require service. With a record of these data available, maintenance scheduling could be based on system need rather than on pre-set time intervals, e.g., the periodic maintenance required by a fan. Depending on load conditions, the time span between cleanings can vary greatly. If maintenance is based on set time intervals, it can be premature or overdue; however, if it is based on performance data, such as decreased flow rate and power requirements, scheduling will be accurate, thus optimizing operations and labor.

The number of parameters monitored on any one unit depends on the amount of information desired. For example, power consumption can be measured toally or broken down by individual components such as pumps and fans.

Monitoring more parameters provides more information. It might be found, for example, that an energy-inefficient system is basically well designed except for one component, and that changing that component could improve the system's efficiency. However, if only total energy consumption is monitored, analysis by component is not possible. However, as more parameters are measured, the cost and effort involved in monitoring becomes prohibitive for this type of analysis.

Cost and Performance Data

The parameters which must be monitored to conduct a cost and performance study fall into three basic categories. The first is consumptions--those items which result directly in costs. Such parameters are electric power, natural gas, water, lime, steam, and absorbers, such as activated carbon or copper pellets.

The second category relates to the operation of the control unit and is used to qualify the cost data. These parameters include the collection efficiency (pollutant concentration before and after the control unit) and flow rate through the unit. With this information, the cost data can be brought to a common denominator for comparisons between units of varying sizes.

The third category of parameters is performance data, such as reliability and availability. These indicate how well the control unit is doing its job. This kind of information can be gathered by placing elapsed time clocks on the control unit and pollutant generator.

The reliability of a control unit can be determined by comparing the amount of time it was actually operated with the amount of time it was required. Availability can be monitored by using a clock which would run whenever the control unit was operable and stop when it was being serviced.

Each cost study must be designed individually to account for variable surrounding conditions. At certain TRADOC installations, for example, an energy conservation study is being instituted which will monitor various energy inputs and consumptions. A pollution control cost analysis at such an installation should consider this to avoid duplication of efforts. Much of the data needed for the cost analysis could be obtained from the energy study, thereby eliminating the need to monitor those parameters.

Current Technology

The technology of automatic data collection has already been developed, and many systems are commercially available. The main task in collecting cost information is choosing the system which best meets the requirements of a particular cost analysis.

Data collection systems range from strip-chart recorders to telemetry systems, and vary widely in complexity and cost. As a system becomes more automatic, it usually costs more to install but requires less labor to operate--and therefore is less expensive to operate when many parameters are being monitored or much data are being collected. The more automated systems are generally more reliable since they depend less on manual labor, thus reducing the amount of missing data.

The most basic automatic data collection system has sensors to monitor the various parameters and strip-chart recorders to record the data. This arrangement is simple and reliable, but manual labor is required to change chart papers, add ink, and check system calibration; later, the data must be transferred manually from the charts to data tapes or cards for analysis, which requies extensive effort. Also, if a recorder runs out of ink or paper for any length of time, the missing data would invalidate the entire set of data taken during that period. Thus, reliable personnel are necessary for this type of system to work.

A slightly more complex system is one which monitors the data similarly, but records the data directly onto magnetic or punched tape. This type of system is available in either a continuous or intermittent recording configuration. The intermittent systems are less expensive to purchase and operate, but provide less detailed information. The advantage of these systems over strip-chart systems is the great reduction in labor requirements. On-site labor is still required to change tapes (although less frequently than strip-charts), but the manual step of transferring data from charts to tapes is eliminated. The reliability of these systems is also higher, since human error is reduced. Occasional system calibration is still required, however, since the same kinds of sensors are used.

A relatively new type of automatic data collection system is a pulse recorder system. This system uses conventional meters, rather than electronic sensors, to measure the various parameters. The meters are interfaced with magnetic tape recorders via simple pulse generators which consist of a magnet connected to a rotating dial on the meter and a magnetically actuated switch. Each time the magnet passes the switch, a pulse is sent to the recorder. On a gas meter, the magnet is placed on the 1 cu ft (0.03 m^3) dial; i.e., each pulse on the tape indicates that 1 cu ft (0.03 m^3) of gas has

been consumed. These cassette tapes, each of which contain four tracks of 1 month's continuous data for four parameters, are then read and the information transferred to computer data tapes via a tape player unit.

The advantages of a pulse recorder system are (1) elimination of expensive sensors, (2) simplicity of operation, (3) continuous data, and (4) elimination of the need for repeated calibrations for most parameters. The only measurement which would still require periodic calibration would be collection efficiency, since a complex monitor would still be involved.

The most complex and expensive automatic data handling systems commercially available are telemetry systems, in which the data are transmitted to a different location for recording and subsequent analysis. A transmitter periodically "calls" a receiver on standard telephone lines and relays information from the sensors to the receiver. Signal conditioners are necessary to interface the sensors with the transmitter, and the electronics involved are complicated.

The advantages of this type of system are (1) no operations labor is required, (2) the data are already on computer tapes, which eliminates a transfer step, and (3) many remote stations can be serviced simultaneously by a single receiving-recording unit. The disadvantages of this system are high cost and intermittent data.

An automatic calibrator which periodically checks and adjusts the sensors is available with some telemetry units. This option is preferable where it is difficult to obtain trained personnel. It also improves data reliability.

Sensors

A sensor is a device which translates a physical condition into an electronic signal. Most are simple, small, and require little service. For monitoring air pollution control equipment, the only complex sensor is the pollutant monitor. For particulates, the monitors presently available are relatively reliable; some are even self-calibrating. For sulfur dioxide monitoring, most units require monthly calibration by a trained technician; in addition, any units requiring chemical reagents usually hold only a 7 to 10 day's supply. A few newly developed monitors which operate on the ultraviolet light absorption principle are potentially more reliable and maintenance-free than other systems. Some of these units are self-calibrating; however, they still require routine monthly maintenance. This type of unit would be best adapted for a cost-analysis type of application.

A simple way of extracting reliability and availability data from a pollution control system is to connect elapsed time clocks to the main power supplies of both the control unit and the pollutant

generator. The desired information can be obtained by comparing the time that a control unit is actually operated with the time it is needed.

Generally, the type of automatic data collection system which is best suited for any given operations and cost analysis depends on the conditions surrounding the study. It is suggested, however, that a system be chosen that either can be serviced by on-site personnel or that has a service contract with a nearby agency, since missing data are highly detrimental to any study. Also, since the more automated systems pay off only when large volumes of data are being gathered, it is best to keep the system as simple as possible while still insuring its reliability.

3 MANUAL DATA COLLECTION

Some of the data necessary for an operations and cost analysis cannot be monitored with automatic techniques. These include operations and maintenance labor and replacement parts. Labor can be monitored by a time clock, but this measures only total hours rather than hours per task. One 8-hour day could be spent on one task or several, so unless a separate worksheet is kept, there is no record of the labor required for maintenance of a particular piece of equipment. Separate worksheets are kept at military installations; however, the way in which work is divided makes cost accounting for individual pieces of equipment difficult. Different shops are responsible for different types of work (e.g., plumbing or electrical) and record their work accordingly. Therefore, to calculate the overall maintenance cost for a single piece of equipment, data from many shops must be compiled.

Collection of operations data is even more difficult. An operator's labor is charged to a facility in total hours, without any breakdown of what work was done. In a heating plant, for example, an operator might work on a boiler, coal feeder, ash-handler, or pollution control unit, and his/her time would still be recorded in the same manner. Any time spent checking or adjusting the operation of a pollution control unit would not be recorded. Although the amount of time spent for an individual adjustment might be relatively small, a substantial difference in the operating cost would result over the life of the unit if this time were ignored. As shown in this example, operations labor is difficult to monitor because it involves many small segments of time rather than a few larger ones.

One means of monitoring operations and maintenance labor would be for the foreman in charge of the facility to keep a log. This person is already responsible for collecting operations data such

as boiler output and fuel consumption, so little reorganization of the present system would be required. However, this might overburden the recordkeeper if he/she already has considerable data to collect. In addition, missing data, which could be a common occurrence with this type of system, would be very undesirable in making a cost analysis.

U.S. Army Construction Engineering Research Laboratory (CERL) researchers discussed labor accounting with the Chief of Utilities at a representative Army installation. In his opinion, using logs was a dependable way of collecting data at some installations, but not at others. Missing data on equipment operations are common where controls are lax, and it is doubtful that additional logs would be accurately kept voluntarily. For this reason, a system which can produce reliable data under various operating conditions is advisable.

Such a system could use the present Army accounting system known as the "Z" accounts.[2] As designed, this system is broken down into codes, which are further divided into activities and performance factors. This system allows for close accounting of operations and maintenance costs. An example of how this system is arranged would be the "K" code known as "Maintenance and Repair of Real Property." Within this code, any work done on "Utility Systems" falls into the "1000" series. "Water Systems" is the "100" subseries and is divided into "Treatment and Filtration," "Wells," and "Distribution Systems" ("10," "20," and "30," respectively). Finally, "Distribution Systems" is broken down into "Mains and Laterals," "Pumping Stations," and "Storage" ("1," "2," and "3," respectively). Therefore, any repair work done on pumping stations would be charged against .K1132, no matter which shop was doing the work.

Interviews with the Chief of the Work Coordinating Office at an Army installation suggested that the "Z" accounting system would be very adaptable to the type of equipment monitoring needed for an accurate operations and cost analysis. A modification of the system would be required to include air pollution control equipment as a separate category, but little additional effort would be required. Since work on pollution control equipment must be charged to some account, this change would simply be to designate certain accounts for the purpose. Since most air pollution control equipment will be installed at boiler plants, the logical places to insert these activities would be in the "4000" series of the "J" code for operations labor and in the "1400" series of the "K" code for maintenance labor and parts. This type of accounting system is advisable for this application, since it would provide the necessary data with a minimum of effort.

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[2] *Operation and Maintenance, Army, 1974*, AR 37-100-74 (Department of the Army, June 1973), Section XII, "Base Operations Z Accounts (Codes .B0000-.N0000)."

If more than one pollution control unit is placed at an installation where a cost analysis is desired, a further breakdown of the accounting into the type or size of the units should suffice to keep the data separated.

When the cost data are collected into the accounting system, a manual step is still required to transfer it to the computer data tapes for analysis along with the automatically collected data.

4 SPECIFIC CONSIDERATIONS

This chapter discusses which parameters should be monitored for various types of air pollution control systems, how each of these parameters can be monitored (automatically or manually), and specific considerations related to assessing the operation and cost of these systems. TM 5-815-1[3] was used as a guide in preparing this chapter to insure that all necessary parameters were included.

Cyclones

The parameters which must be monitored in the operation of a cyclone collector for the purposes of a cost and performance analysis are flue gas flow rate, particulates in and out, power consumption, labor requirements, times of availability, operation, and demand, plugging, and erosion of the walls. All of these are suited to automatic data collection except labor, erosion, and plugging.

Labor can be monitored by one of the manual systems already discussed. Erosion of the walls must be observed and noted manually; however, the costs associated with erosion will be accounted for in the replacement parts and labor costs incurred by the replacement of wear plates.

Plugging of tubes is not a directly measurable parameter of operation; however, it does incur additional costs. The only practical method of recording the occurrence of plugging is by keeping a manual record. On the other hand, the costs associated with plugging, such as reduced collection efficiency and additional labor for cleaning, will be accounted for indirectly in other areas.

The dust hopper operation can be monitored by using an alarm which records occurrences of high dust levels within the hopper. These alarms would in turn indicate a failure of the hopper unloader.

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[3] *Air Pollution Control Design Manual*, TM 5-815-1 (Department of the Army, in publication).

In the special case of a wet cyclone, where a water spray is used to increase collection efficiency, water consumption must also be monitored to account for the additional cost.

Baghouses

The parameters which must be monitored in the operation of a baghouse collector for the purposes of a cost and performance analysis are flue gas flow rate, pressure drop, particulates in and out, inlet gas temperature, fan power consumption, labor requirements, times of availability, operation, and demand, the cycle time between bag cleanings, bag failure rate, and bag cleaner failure. These are all easily monitored with the exception of the failures of bags and bag cleaners.

A sudden decrease in pressure drop not associated with the cleaning of the bags or a reduction in collection efficiency would indicate bag failure. However, the only reliable method of obtaining an accurate indication of the exact number of bag failures is to keep a log recording the number of bags found to be defective on various inspections. The cost associated with these failures will be accounted for within the replacement parts costs.

The purpose of monitoring inlet gas temperatures is to determine whether the capabilities of the bags in use are being exceeded. Flue gas temperature may contribute to a high rate of bag failure; changing to a high-temperature material such as fiberglass might be appropriate when the bag failure rate is high. A comparison of bag failure rate with operating temperature would thus be very helpful in selecting the proper bag for a specific application.

Bag cleaner (whether shaker or air jet) failure will be indicated by a reduction in cycle times between cleanings, but cannot otherwise be directly monitored. Again, the costs will be covered in other areas, such as replacement parts and labor, but a record of failures would be a more direct and practical means of identifying the problem.

Electrostatic Precipitators (ESP)

The parameters which must be monitored in the operation of an ESP for the purposes of a cost and performance analysis are flue gas flow rate, particulates in and out, fan power consumption, corona wire power consumption, labor requirements, times of availability, operation, and demand, corona wire failure rate, rapper failure, and control system failure.

Wire failure will be indicated by a decrease in the wire power consumption and a decrease in the collection efficiency. The associated costs will be accounted for in labor and replacement parts costs.

Rapper failure would be indicated by a high degree of dust re-entrainment or a drop in collection efficiency. There is no direct way to monitor such failures other than by recording them in a log; however, the associated costs will show up in labor and replacement parts.

The electric power control system is an important part of any ESP. It basically consists of a step-up transformer, high voltage rectifier, and voltage and amperage controls and sensors. It would be impractical to monitor each of these components continuously for purposes of an operations and cost study; however, it would be useful to record any problems or failures in a log.

In some cases, water is used to improve collection efficiency or to wash the collector plates rather than rapping them to remove the dust. In these cases, water consumption must also be monitored as an additional cost.

Scrubbers

The parameters which must be monitored in the operation of a wet scrubber for the purposes of a cost and performance analysis are flue gas flow rate, pressure drop, pollutant concentration in and out, water consumption, reagent consumption, fan power consumption, auxiliary component (pumps and controls) power consumption, labor requirements, times of availability, operation, and demand, and sludge treatment and disposal costs.

The sludge handling system associated with a scrubber can consist of many components, each having its own related operational costs. Examples of these are flocculators, mixing tanks, pumps, and sedimentation basins. Any power, water, and chemical consumptions of these units should be included in the total consumptions of the scrubber system, as should labor and replacement parts. The only additional cost incurred would be that of final waste disposal. This could either be measured directly by assigning a cost per unit volume of sludge and monitoring the flow of the waste; or indirectly, by using the cost of the land space consumed or the cost of hauling if done on contract. At any rate, it is an important cost associated with scrubber operation and should not be overlooked.

Emerging Systems

Many new systems for the control of particulate and gaseous emissions are currently under development. Some of these are merely modifications of existing systems and can be evaluated using techniques already discussed. Others, however, use new methods of treatment and will not fit into one of the above categories. In the event that such a system is to be evaluated from an operations and cost standpoint, some basic guidelines can be followed to insure that an accurate analysis is performed.

First, all consumptions, such as power and water, should be monitored for cost purposes. Second, flue gas conditions before and after treatment are important from an operations and performance point of view. These would include items such as flue gas flow rate and pollutant concentrations. Third, labor--both operations and maintenance--must be recorded, since it can incur significant costs and can determine whether a system is practical for certain applications. Fourth, replacement parts must be monitored from both cost and system reliability standpoints. Finally, any waste disposal costs or problems must be determined, since these can also make an otherwise workable system infeasible.

5 APPLICATION

After the cost and performance data are collected, they must be converted to arrive at the desired information. The direct cost data must be multiplied by the appropriate unit costs for each item consumed and adjusted for the time period of the study. If a projected cost study were done, the same cost data would be used, since consumptions for any given control unit would remain constant; however, the monetary multipliers used would have to be adjusted to account for inflation.

The operations data, such as stack gas flow rate, are used to adjust the cost data to a common denominator. When this is done, the costs are expressed as "dollars per standard cubic foot of treated effluent," allowing comparisons between units of differing output.

The performance data (reliability, availability) are not influenced by the value of money and therefore do not need to be adjusted for inflation. However, it might be desirable in a cost analysis to assign a cost to noncompliance with local standards, such as the amount incurred by a fine. The figure derived by multiplying this amount by the number of days a unit failed to operate would allow direct comparisons between units having different reliabilities. Although it is likely that fines for noncompliance

will increase in the future, it is difficult to assign an estimated rate of increase. A decision about the amount to use must be made at the time a study is conducted.

6 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The only definite means of obtaining accurate cost and performance data for air pollution control equipment is to actually monitor the equipment's operation. This information is necessary for choosing future equipment and will enable efficient operation of the equipment.

The technology needed for detailed monitoring is presently available; however, the system chosen by the user must be compatible with conditions surrounding the study. Factors which determine this compatibility are (1) number of parameters to be monitored, (2) labor available, (3) reliability of personnel, and (4) availability of service for the monitoring system.

Recommendations

The techniques described in this report for collecting cost and performance data should be considered by the Office of the Chief of Engineers and major command engineers whenever an air pollution control device with which the military has no previous experience is to be installed at an Army facility. Since the techniques have not been field tested, an evaluation program for adequacy of these techniques leading to appropriate modification should be instituted in their first application.

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